the height of the structure must be considered. Dense cities with clustered areas of large buildings are the most likely to require augmentation of satellite coverage with terrestrial repeaters. Such locations require supplementary coverage because large clusters of buildings with dissecting roads cause shadowing on multiple sides at very high elevation angles. However, large isolated buildings do not necessarily cause blockage. Distance from the roads and building orientation versus the satellite's elevation angles must also be considered. Moreover, long tunnels, ravines and similar topography will also require additional terrestrial augmentation, primarily due to the lack of line of sight coverage from the satellites.

B. Typical Terrestrial Repeater System

The number of terrestrial repeaters required is inversely proportional to the satellite coverage. In other words, the less blockage and attenuation, the fewer terrestrial repeaters required. The high elevation angles resulting from SSR's geosynchronous orbits dramatically reduce the expected blockage as well as the foliage attenuation (by more than 20 times) when compared to geostationary satellites for the northern half of the United States. The dense city environments, which are the major areas of concern, are mostly located in concentrated areas. Of the major cities in the US, less than fifty are anticipated to require substantial terrestrial repeater coverage and roughly the top ten will require several repeaters in a single frequency network configuration ("SFN").

A single frequency network consists of a number of transmitters using the same frequency to emit identical program material to the coverage area. It can thus be considered to be a special case of a multipath channel, where the late arriving signals may be of the same level as the direct path, or even higher. A SFN delivers a signal from several transmitters carefully aligned, broadcasting precisely synchronously, with the correct spacing, and at exactly the same phase and time. When received by a receiver, these signals collectively combine and provide for excellent coverage and clarity. This quality is achieved despite the existence of physical objects that would disturb a conventional signal. Another benefit, is that with all the transmitters for a given SFN operating on the same frequency, there is no need for the listener to re-tune the radio (*i.e.*, "soft handoff") while driving in a car in order to follow a given program within the service area of the SFN.

SSR will minimize the number of repeaters required in urban areas by careful engineering of site locations and power. This strategy will allow the necessary coverage area in over 75% of the target urban areas with only one or two sites. The ten larger urban areas require additional repeaters in a single frequency network configuration to provide the required terrestrial coverage. Again, a group of separately engineered, low transmitter power Coverage Extenders will be utilized in poor topographic areas and tunnels.

C. Terrestrial Repeater Power Levels and Limits

The SSR geosynchronous satellite design provides excellent coverage while minimizing repeater requirements. SSR's design thus calls for the construction of relatively few such repeaters nationwide, and an average of less than 3 in any one urban area. These terrestrial sites exploit modern technology and utilize high gain antennas to provide EIRPs up to 40 kW within the S-band. Such broadcast sites can provide coverage to supplement the satellite up to a radius of twenty miles depending on the local terrain and tower height. Where multiple sites are planned in a single area, SSR may employ shorter, lower power, more closely spaced sites to provide adequate terrestrial coverage.

III. Experimental System Results

In establishing an allocation for SDARS, the Commission deemed complementary terrestrial DARS to be an adjunct to a satellite-based system, rather than a separate, stand-alone terrestrial service.[3] Further, as part of the rule making process to determine service rules for SDARS, the Commission issued a *Further Notice* that confirmed the importance of maintaining sufficient service link margin to reproduce the original information transmitted by satellite.[4] Additionally, in the *Further Notice* the Commission asked how it could determine use of terrestrial repeaters actually was complementary to SDARS.[5] In order to aid the Commission in these determinations, SSR applied for and received FCC experimental authorizations in two locations. These locations, San Francisco and Houston, were selected due to their differing terrain and propagation characteristics. The results from these tests demonstrate that terrestrial repeaters are viable and do not cause harmful interference to adjacent channel licensees.

A. Terrestrial Network Testing in San Francisco

In order to fully test in the San Francisco Bay area, three sites were constructed to evaluate the S-band coverage and performance achieved as well as to set guidelines for equipment, subsequent deployments, and system performance.

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3 *See* Amendment of the Commission's Rules with Regard to the Establishment and Regulation of New Digital Audio Radio Services, GEN Docket No. 90-357, *Report and Order*, 10 FCC Rcd 2310 at ¶ 2.

4 *See* Establishment of Rules and Policies for the Digital Audio Radio Satellite Service in the 2310-2360 MHz Frequency Band, IB Docket No. 95-91, *Report and Order Memorandum Opinion and Order and Further Notice of Proposed Rulemaking*, 12 FCC Rcd 5754, 5808 at ¶¶ 138-144 ("*Further Notice*").

5 *Id.*

1. Purpose of Interference Testing

The tests had three goals: *First*, to finalize repeater design; *second*, to demonstrate the effectiveness of that design and, *third*, to coordinate with users in adjacent bands. To accomplish the last goal, the site operating companies were informed of the test program and asked them to bring any reports of interference from tower users or others to SSR attention.

2. Test Process

System testing was executed to evaluate coverage and performance characteristics. The testing campaign utilized a test van and S-band receiver and a single frequency network of three S-band transmitters. System measurements and drive tests were performed on individual sites as well as the Single Frequency Network ("SFN") in San Francisco. These tests provided data for the following parameters: Bit Error Rate ("BER"), Signal Strength, Channel Impulse Response ("CIR"), and Doppler spreading as per the descriptions below. Data was recorded along with GPS coordinates for positional information.

Testing was performed to determine the coverage area and boundaries for each of the three single sites as well as a two-site and three-site SFN. For each of the three- (3) sites in San Francisco, drive test data was collected associated with the following measurements:

- Bit Error Rate ("BER") & Cyclic Redundancy Check ("CRC")
- Signal Strength
- Channel Impulse Response ("CIR")

The network was configured with two sites and then three sites in a SFN. The SFN allows the simultaneous transmission of multiple sites on the same frequency without interference. SFN testing with two (2) sites transmitting simultaneously included the following measurements:

- BER & CRC check
- Signal Strength
- CIR
- Doppler Testing

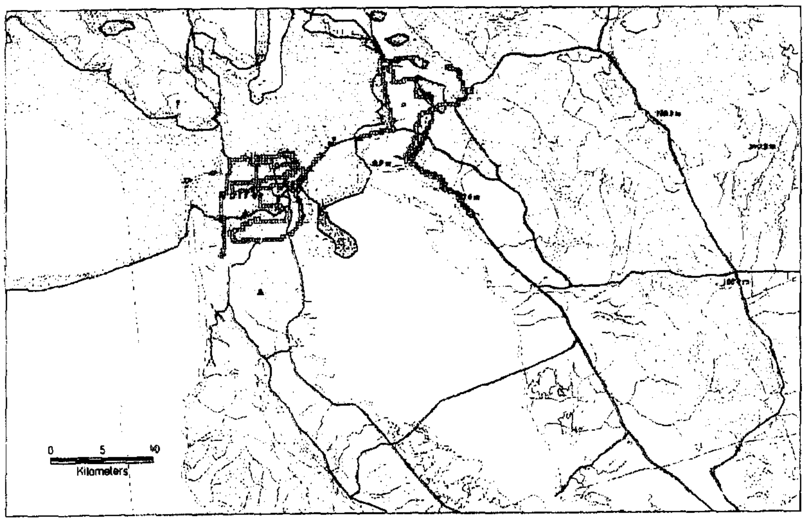
SFN testing with all three (3) sites transmitting included the following measurements:

- BER & CRC check
- Signal Strength
- CIR

3. Test Results

The signal strength determined the extent of coverage while the BER and CIR helped determine the quality of the received data throughout the coverage area. As an example of the testing results, the figure below shows the predicted service availability and measured coverage for a single site.

Results for Single site operation - Mt. Sutro
Bit Error Rate (BER) & Service Availability



Simulation of Service Availability

- 90 - 95 %
- 95 - 99 %
- 99 - 100 %

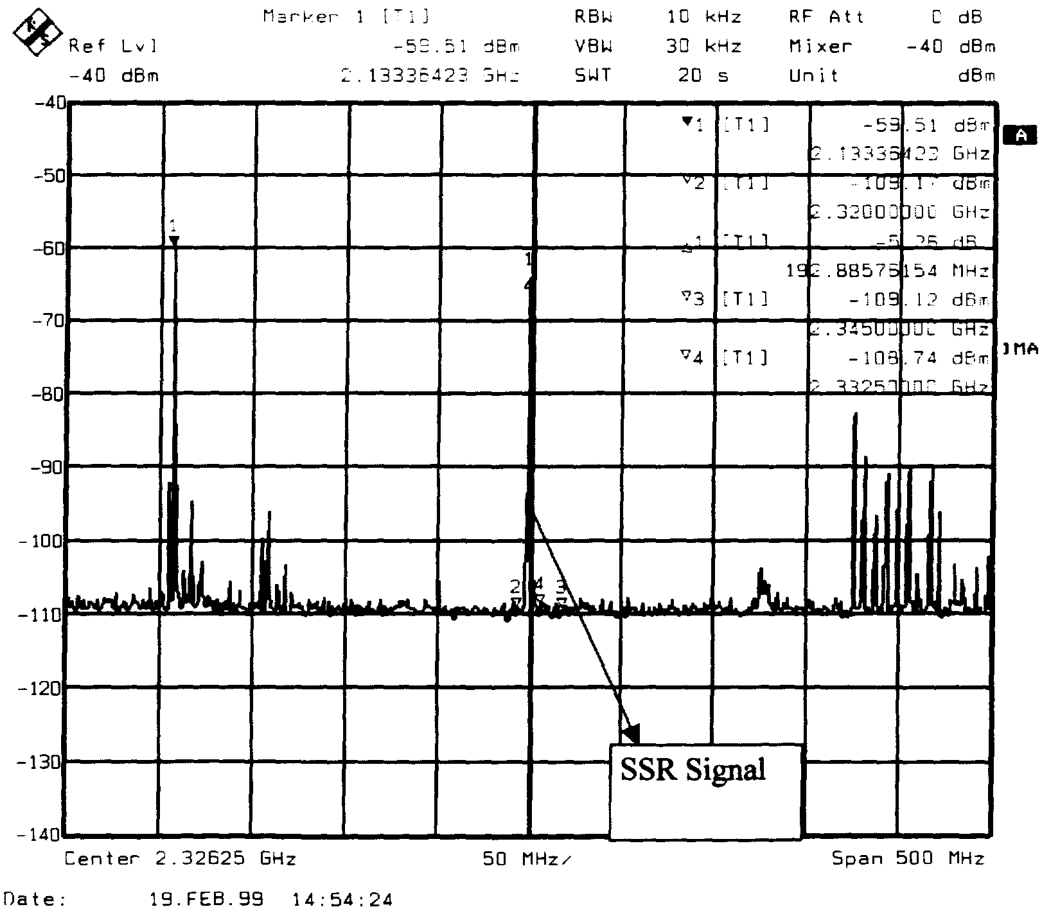
Measured BER

- 1E-7 ---> 1E-3
- 1E-3 ---> 1E-2
- 1E-2 ---> 1E-1
- 1E-1 ---> 1E 0

Measured BER is the measurement of 'raw' channel errors and should be interpreted as 'Uncorrected Values'

3. Single Frequency Network Configuration and Testing

Prior to utilizing transmitters at full power, gradual power turn up of each transmitter was performed in coordination with other FCC licensed site occupants. The coordination was successful in showing that no interference occurred at any of the sites. Below is a plot of the spectrum showing the SSR transmit signal as well as other signals within a 500 MHz span at a point in downtown San Francisco.



Over-the-Air Spectrum Measurement

For San Francisco, additional analysis was performed to verify that the sites were within the limits of the FCC's hazardous emission requirements for controlled and uncontrolled conditions. Results of the analysis showed that controlled conditions were met under the worst case EIRP of 40kW at S-band.

4. Conclusions

Final analysis included a detailed assessment of the individual sites, SFN testing and a performance comparison and evaluation. Performance comparison and evaluation means a comparison of measured results to calculated coverage based upon modeling by a prediction tool for COFDM transmissions. In conclusion, the sites provided more than adequate coverage and the single frequency network of sites was configured to provide excellent quality supplemental coverage in downtown San Francisco. The downtown area tested is the key area requiring augmentation of the expected satellite coverage and SSR's experimental testing demonstrated that terrestrial repeaters, in a very minimal quantity, were able to provide supplementary coverage in the Bay area.

This coverage was obtained without any complaints of interference being reported from co-located tower users or others.

B. Terrestrial Network Testing in Houston

Houston was the second urban area selected for experimental testing. Houston has significant climatic and terrain differences from San Francisco (*i.e.,* Houston is hot and flat) and was selected as an additional test site to highlight that these severely disparate areas could be supported by terrestrial repeaters.

SSR's strategy for Houston is to utilize one site located on a tall building downtown to cover the metropolitan area. A portable test transmitter and applicable test receiver were utilized to perform coverage and quality testing. The testing showed extensive coverage and good quality for the target coverage areas. In addition to performing the same tests in Houston as were performed for a single site in San Francisco, interference testing was performed with co-located users.

1. Purpose of Interference Testing

Coordinated interference testing with owners of certain receivers, including law enforcement, was performed on the Chase building where current plans are to locate a terrestrial transmitter. The testing was to verify operation of the SDARS transmitter without interference to existing users and co-located receiver occupants (some of which utilize frequencies at the edge of the SDARS band).

2. Test Process

The SDARS transmitter and antenna locations were set up to represent as closely as possible the proposed operational arrangement at Chase tower, including EIRP's and antenna locations. The transmitter, with 4 antennas positioned for coverage from the four corners of the building, was turned on and off for several hours in a coordinated fashion while the existing users viewed their level of service on a variety of channels for any service disruption. The existing users had already established a test plan suitable for evaluation of their respective services as part of the preparation for the test.

3. Test Results

As in San Francisco, the Houston tests proved that the SSR repeater design caused no undue interference to adjacent band users. In addition to the foregoing, SSR also was able to garner specific information about interference issues between SSR and a variety of adjacent spectrum users.

a. TV ENG (Electronic news gathering)

Local TV stations were using frequencies in the range 2450 to 2483.5 MHz for ENG. Chase tower was the location for the receiving end of the links which employ directional antennas with built in pre-amps. After the conclusion of the testing no impact was reported to these co-located receivers.

b. Law enforcement

Law enforcement personnel from a variety of agencies operate systems for portable and fixed video surveillance operations, on a number of frequencies including those in S Band allocated near the SDARS band. Although specifics were not provided to SSR, law enforcement agencies in Houston and nationwide use remotely steerable high gain receiving antennas, and very low power transmitters. After conclusion of the testing there were no reports of harmful interference, although some non-service affecting interference was noted on one channel immediately adjacent to the SDARS band at a receiver collocated on the rooftop. This was considered by the user to be within limits acceptable and workable for operations.

4. Conclusions

The San Francisco and Houston tests proved that the SSR terrestrial repeater design is satisfactory and practical. The activities in Houston also provided an opportunity to gain an understanding of the operations of adjacent band users, particularly law enforcement, close to the SSR SDARS allocation and to confirm SSR operations would have no impact on Electronic News Gathering (ENG) services. As a follow up to the testing in Houston, a coordination approach was suggested by the representatives of the various law enforcement departments, involving consultation with the main manufacturer of the equipment used , as apparently almost all law enforcement apparently employs equipment from the same manufacturer.

IV. Out-of-band Emission Requirements

A. Development of Emissions Specification

SSR, in cooperation with the other SDARS licensee, XM Radio, has developed a specification for a terrestrial repeater RF emission mask, which takes into account the following factors:

- FCC regulations as regards out of band emissions;
- Emissions coordination with the other SDARS licensee XM Radio;
- Interference to SSR's own satellite signals in the adjacent channels within SSR's allocated section of the SDARS band; and
- Adjacent band operations[6]

In assessing the emission mask requirements, the FCC out of band emissions limitations were found to be insufficient to guarantee that the two SDARS licensees would not seriously impact each other's service levels. Therefore, a much more stringent emissions specification was developed. This more demanding emission limit, set by mutual agreement between XM Radio and SSR regarding the emission levels outside of the individual SDARS allocations, (i.e., 2320 to 2332.5 and 2332.5 to 2345 MHz) is as follows:

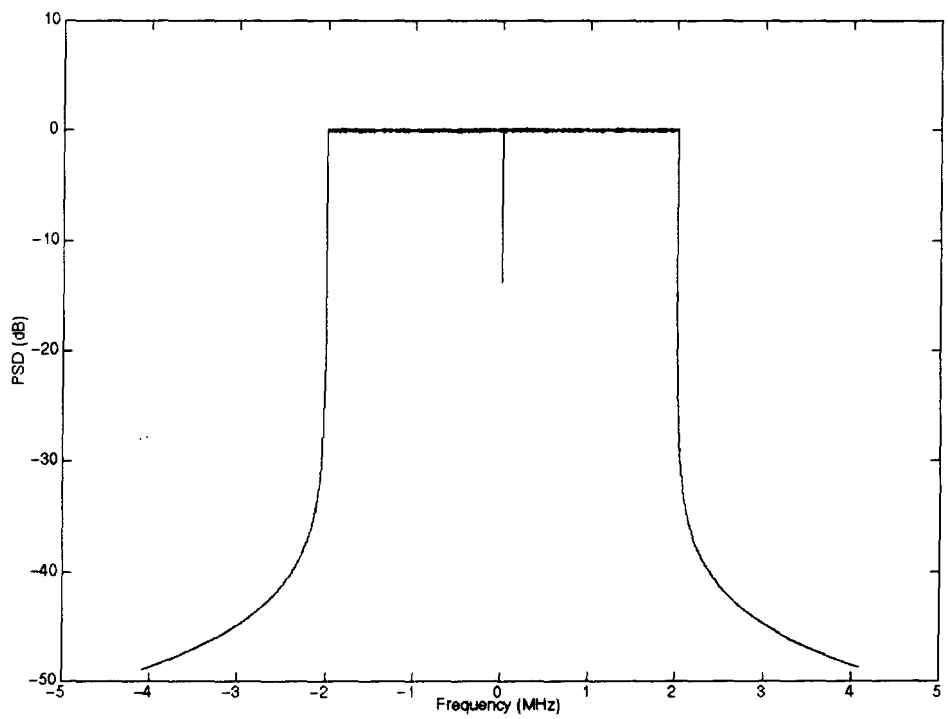
> The EIRP of SSR's emissions outside of the range 2320.0 to 2332.5 MHz shall be attenuated below the terrestrial repeater EIRP (P_{EIRP}) measured in Watts, within the licensed band of operation, by a factor not less than $75+10\log(P_{EIRP})$ dB.
>
> Compliance with these provisions shall be based on the use of measurement instrumentation employing a resolution bandwidth of

[6] *See* Exhibits 1 & 2 on interference analysis for WCS and MMDS/MDS/ITFS from SDARS

> 1 MHz or less, but include at least 1% of the emission bandwidth of the fundamental emission of the transmitter, providing the measured energy is integrated over a 1 MHz bandwidth.

Meeting these levels required SSR to add substantial filtering to taper the "skirts" of the terrestrial repeater emission mask. The overall emissions requirement is met by a combination of spectral roll off of the COFDM signal (see basic spectrum below) and additional significant transmitter output bandpass filtering.

Simulated SSR COFDM Waveform



Note that this emissions requirement, necessary to prevent mutual interference between the two licensees, is far more stringent than any pre-existing out-of-band emission limitations. In particular it is expressed in terms of EIRP rather than the more usual transmitter output power. This ensures extremely low emissions levels, regardless of the actual site specific antenna gain used since it essentially limits all out of band emissions to be less than –45 dBm in a 1 MHz BW regardless of transmitter power or antenna gain. Other specifications in terms of transmitter output power leave ambiguity with regard to the actual radiated emissions due to the variety of antenna gains that can be used in actual deployment.

B. Comparison with Existing FCC Requirements

In order to demonstrate the strictness of the proposed emission mask, a comparison between existing FCC requirements and SSR's proposal is necessary. The following is a comparison with Section 25.202 (f) of the Commission's rules:

> (f) Emission limitations. The mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the following schedule: (1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB; (2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB; (3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts.

Differences Between SDARS and FCC Emission Mask Formulas. In comparing the FCC emissions limits with those proposed by SSR and XM Radio, its important to note that the SDARS mask is referenced to EIRP rather than transmitter output power and that a 1 MHz resolution bandwidth is proposed by SSR rather than the 4 kHz bandwidth contemplated by the Commission. In order to accurately compare the two formulas, a couple of corrections are therefore necessary:

• *Resolution Bandwidth:* Current rules require measurement over 4 kHz; this is insufficient for the wide-band signal that each satellite DARS licensee will transmit. In order to adjust for the differences in resolution bandwidth, an additional 24 dB must be applied to the SDARS formula (75 + 10 $\log_{10}$ (P_{EIRP})) due to the following correction factor formula:

10 log10 (4000/1000000) = -24 dB

where 4000 is the 4 kHz resolution bandwidth required by the Commission formula and 1000000 is the 1 MHz resolution bandwidth proposed by SSR.

• *Transmit Power and Antenna Gain:* Adjustment also has to be made based on the actual antenna gain employed in order to compare the results of applying each specification. For the purposes of this analysis, we have assumed a transmitter output power of 1 kW and an antenna gain of 10 dBi, each of which would be typical in the SSR terrestrial repeater design.

With these adjustments in order to normalize results in the two formulas, the following table gives a comparison between the Section 25.202(f) emission mask requirement and the actual emission limit to be utilized by SSR in terms of maximum emission levels.

As can be seen, the SSR limits proposed are significantly more stringent than that required by 25.202 (f). Moreover, adjacent band systems will be protected by 60 dB or more over the current FCC 25.202 (f) requirements in this particular example. Such substantial protections from out-of-band and spurious emissions should cause no harmful interference to adjacent operations.

Comparison of SDARS Emission Requirements and FCC 25.202 (f)

	FCC 25.202 (f)		**SSR limits**	**SSR**
Frequency range (MHz)	**% channel bandwidth**	**Level in 4 kHz, EIRP**	**Equivalent Level in 4 kHz, EIRP**	**Margin**
<2316.25	>250%	-3 dBm	-69 dBm	+66 dB
2316.25 to 2320.0	Between 150% and 250%	+5 dBm	-69 dBm	+74 dB
2320 to 2322.25	Between 100% and 150%	+5 dBm	-7 dBm	+12 dB
2322.25 to 2324.25	Between 50% and 100%	+15 dBm	+2 dBm	+13 dB
2324.25 to 2328.25	Center channel	Center channel	Center channel	N/A
2328.25 to 2330.25	Between 50% and 100%	+15 dBm	+2 dBm	+13 dB
2330.25 to 2332.5	Between 100% and 150%	+5 dBm	-7dBm	+12 dB
2332. 5 to 2336.25	Between 150% and 250%	+5 dBm	-69 dBm	+74 dB
>2336.25	>250%	-3 dBm	-69 dBm	+66 dB

1. Summary of Emission Masks[7]

The following emission masks serve to illustrate the more stringent SDARS emission criteria for two example circumstances, namely 2 kW EIRP (SDARS and WCS with 10 dBi antennas) and 40 kW EIRP (SDARS only).

[7] *See* Exhibits 1 and 2 for details on interference analysis for WCS and MDS/MMDS/ITFS.

Figure 1 - SDARS Emission Mask (2KW EIRP)

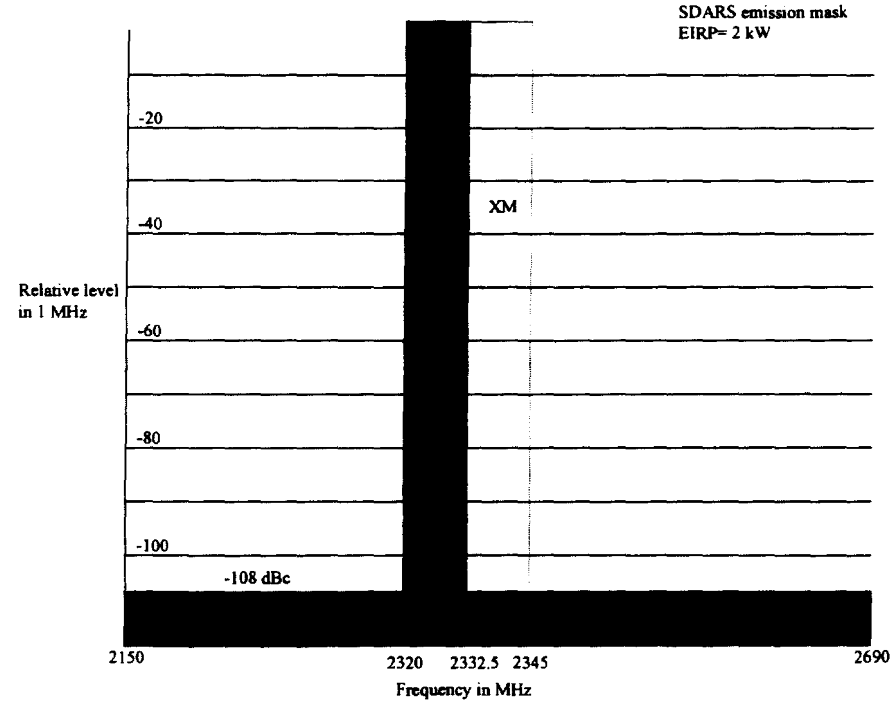


Figure 2 - SDARS Emission Mask (40KW EIRP)

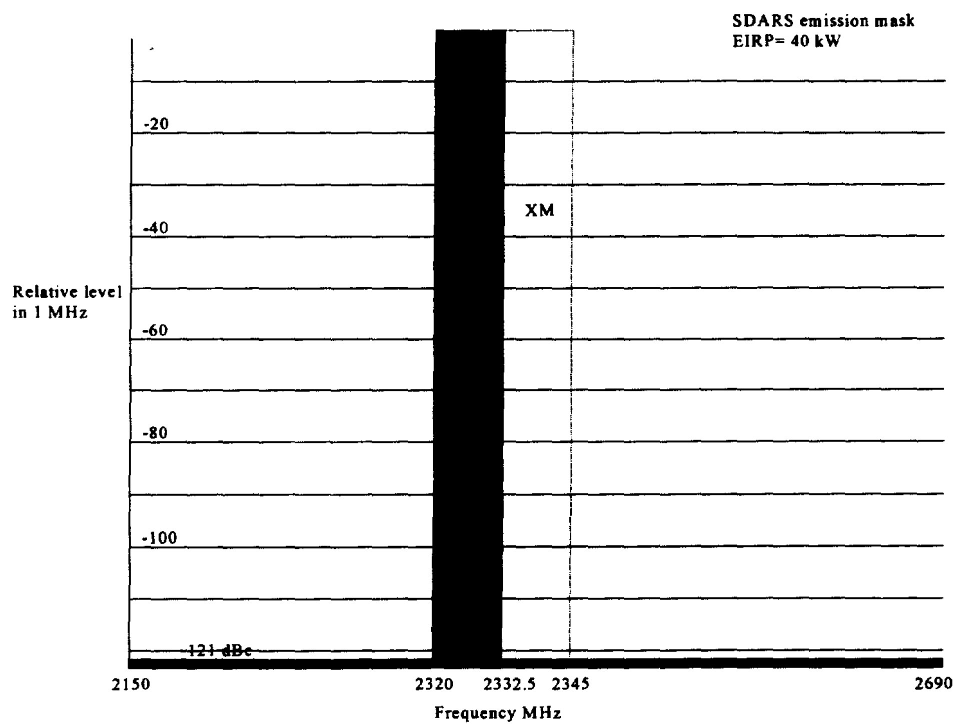
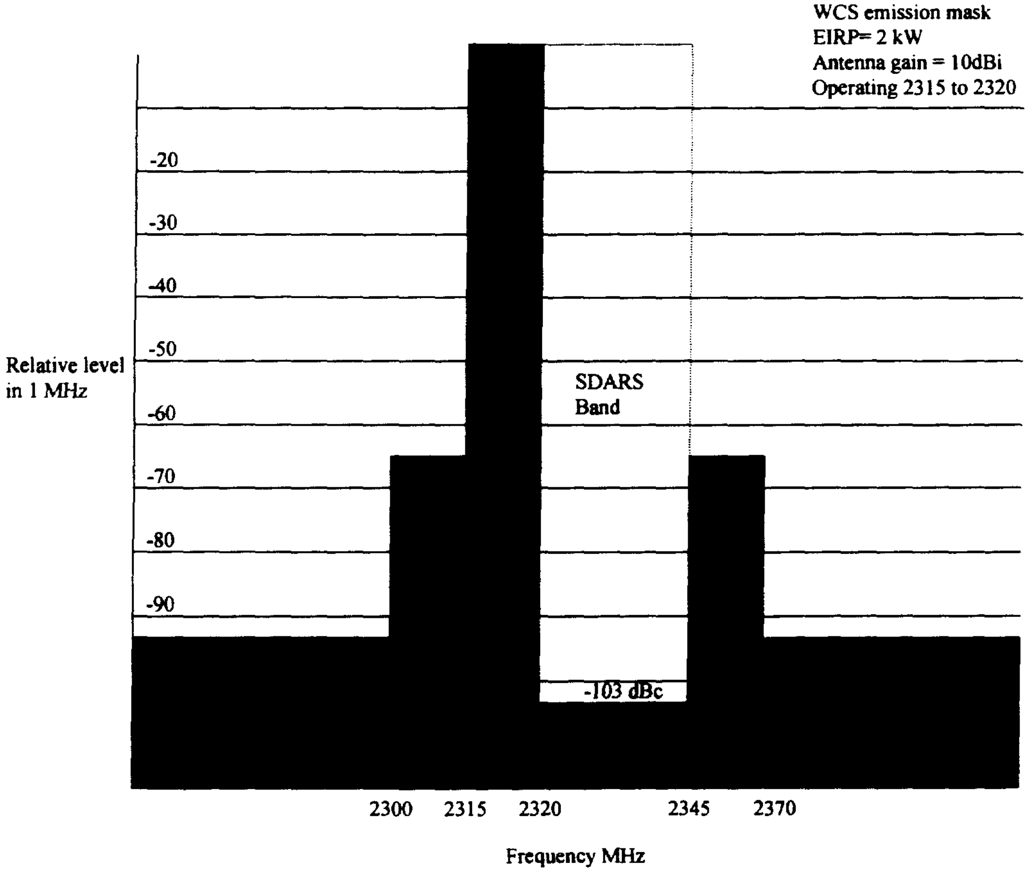


Figure 3 - WCS Emission Mask (2KW EIRP)



C. Summary of Impact on WCS, MMDS users

The out-of-band emissions limit adopted by the SDARS providers ($75+10\log_{10}(P_{EIRP})$) is more stringent than the emission limits required by Section 27.53 of the Commission's rules for WCS, because the SSR emission attenuation is specified with respect to the transmitter EIRP whereas the WCS emission suppression is specified with respect to the transmitter output power into the antenna. Depending on the antenna gain used by the WCS provider, the actual radiated WCS emissions could be even higher with respect to the SSR emissions than the conservative calculations illustrated above. It is clear that the SDARS interference limits are more stringent than those permitted between WCS licensees and between WCS and adjacent services and should therefore impose no significant burden on WCS.[8] Since MMDS/ITFS operates several hundred megahertz away from the SDARS allocation with directional antennas, there will be no or minimal impact on this service from SDARS out-of-band emissions.[9]

V. Hazardous Radiation

A. SDARS Limits

The limitations imposed in terms of power levels for the SDARS band are given as follows:

- 5 mW/ cm^2 for occupational exposure
- 1 mW/ cm^2 for general population/ uncontrolled exposure

In addition to the critical RF safety limits, from a technical perspective SSR believes the maximum EIRP that can be successfully utilized in SDARS is limited by the following factors:

- The maximum available RF power from commercial repeaters of reasonable size and cost.
- The realizable antenna gain useful for satellite coverage gap filling.

SSR has determined these values to be approximately 1 kW and 15 dBI (including cable losses) respectively. This sets an upper-bound on usable EIRP of approximately 40 kW. Certain attributes of SSR's terrestrial technology further reduce this level in the situation where multiple repeater sites are used in close proximity to each other.

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[8] *See* Exhibit 1 on interference analysis for WCS from SDARS

[9] *See* Exhibit 2 on interference analysis for MMDS/MDS from SDARS

In order to minimize the number of repeaters used, a reasonable deployment strategy calls for the use of high sites together with the EIRP's indicated above. These sites, by their nature, are unlikely to be in close proximity to the general public. As mentioned above, the limits for hazardous radiation in the SDARS band are five times higher than those for the FM broadcast service, reflecting the lower absorption levels and therefore, in cases where repeaters are located on existing broadcast facilities with similar power levels, there should be little or no additional impact in terms of hazardous radiation.

B. Example Calculations

1. Conservative

The following graphs gives a conservative view of the implications of this service in terms of the FCC's hazardous radiation rules. In the graphs below, no power level reduction is assumed from the elevation pattern of the antenna and it is assumed that any reflections contribute 100% to the combined level.

Figure 1 below shows the distance beyond which the occupational and non-occupational limits are met. For example, at a power level of 40 kW EIRP a tower height above 17 meters ensures compliance for the general public, zero reflection case and above 35 meters ensures compliance for the most conservative case, namely 100% reflection, general public case.

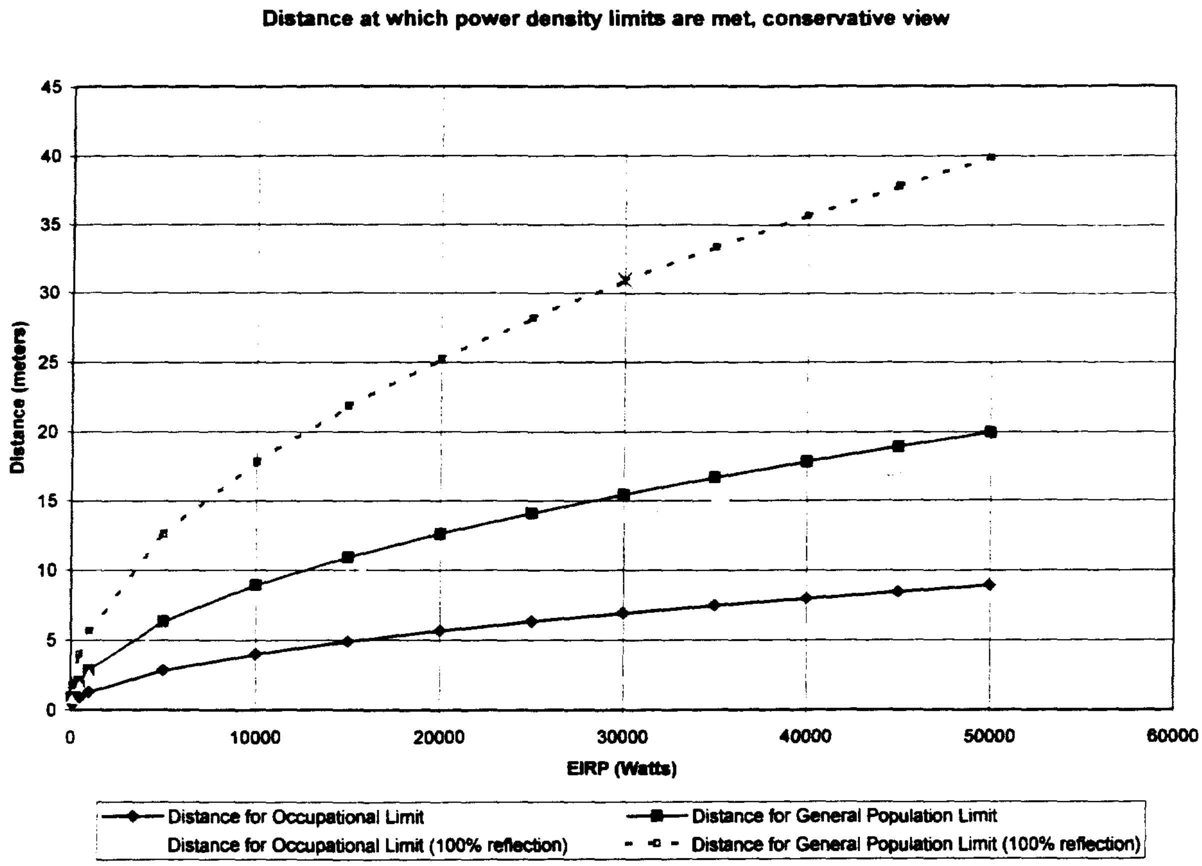

Figure 4 Hazardous radiation limits, conservative

2. Nominal

A more realistic calculation includes the attenuation that is achieved from the elevation pattern of the antenna. Figure 2 shows the result of including the typical elevation attenuation attainable from the type of antennas used by SSR.

As can be seen, the worst case compliance distance is now <18 meters for a 40 kW EIRP and 100% reflection.

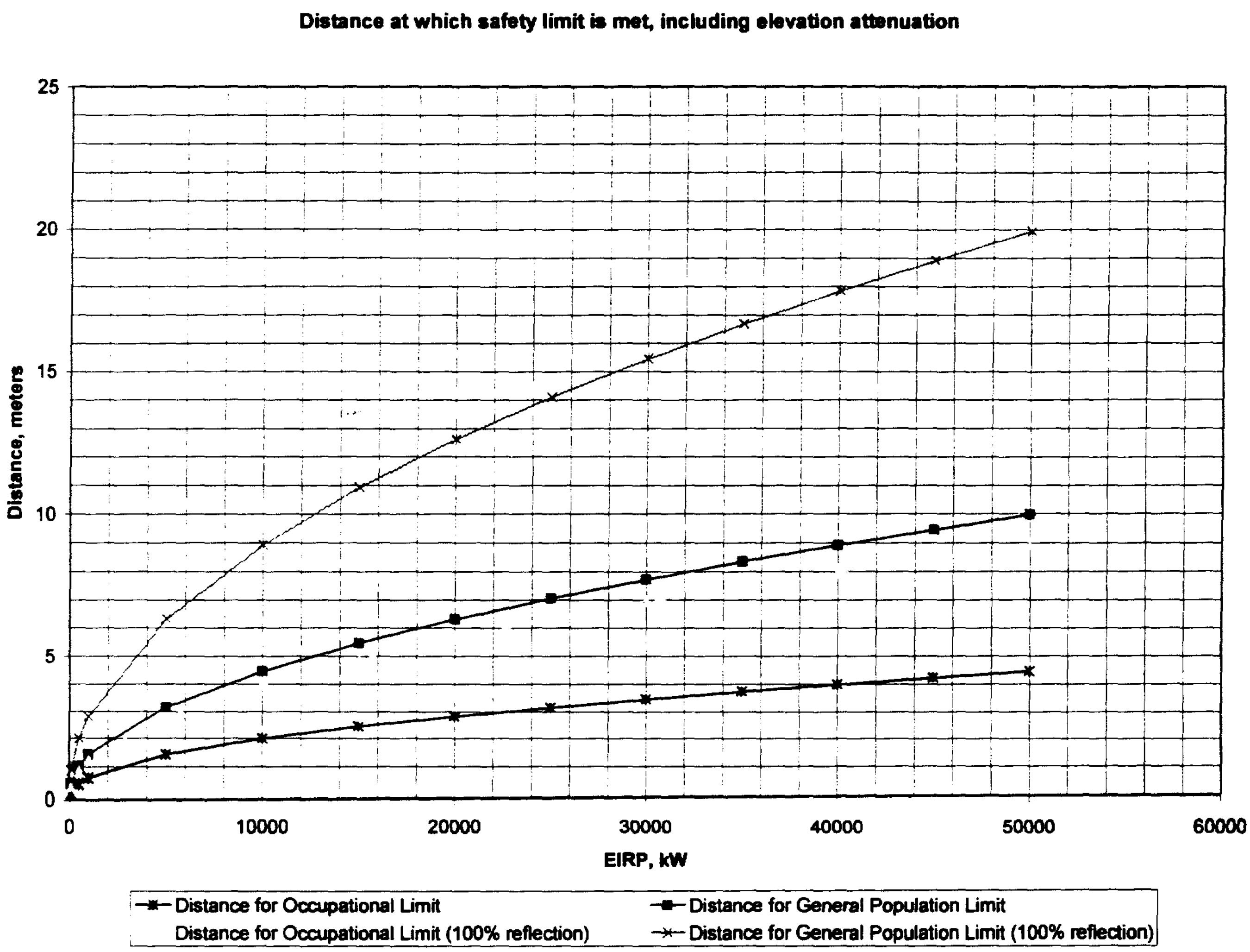

Figure 5 Hazardous radiation estimate including elevation attenuation

C. Summary

SSR's design and deployment of terrestrial repeaters, intended to meet its service coverage objectives, will not introduce hazardous radiation in violation of the Commission's guidelines. Indeed, SSR's choice of high towers on mountains or rooftops should simplify compliance especially regarding the general public.

VI. Conclusions

SSR has previously provided analyses and now has completed measurements of its planned SDARS terrestrial repeater network. The program of experimentation demonstrates that:

1. Expected excellent high-elevation satellite coverage minimizes the number of terrestrial repeaters needed. Nonetheless, coverage of possibly blocked core urban areas can be accomplished with a limited number of terrestrial repeaters with EIRP values up to 40 kW and relatively high antenna heights. The SSR preliminary design will provide sufficient terrestrial augmentation of satellite signals in San Francisco with three such repeaters; only one repeater is required in Houston. For the entire contiguous United States, SSR expects to employ fewer than 200 high power terrestrial repeaters.

2. Some areas must be augmented with low power terrestrial repeaters (*i.e.,* less than 1 kW EIRP) to provide service in tunnels, long underpasses, ravines, etc. Less than three hundred of these low power, localized signal terrestrial repeaters are required. These low power systems will have little or no potential to interfere with nearby services.

3. The stringent emissions specification proposed by the SDARS industry provides interference protection significantly in excess of any existing service requirement.[10] Operating experience and measurements indicate that experimental SDARS terrestrial repeaters do not interfere with adjacent band services. Indeed, operations in San Francisco have been conducted for almost a year without any report of interference, and interference investigations in San Francisco and Houston have shown no problems.

4. SSR's proposed terrestrial repeaters will fully comply with the agency's radiation hazard requirements.

[10] *See* Exhibits 1 & 2 on interference analysis for WCS and MMDS/MDS from SDARS

<u>CERTIFICATE OF SERVICE</u>

I hereby certify that on this 18th day of January, 2000, I caused copies of the foregoing Supplemental Comments of Sirius Satellite Radio to be mailed via first-class postage prepaid mail to the following individuals on the attached document:

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